Agricultures
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Collection Cirad-AFD

Living territories to transform the world

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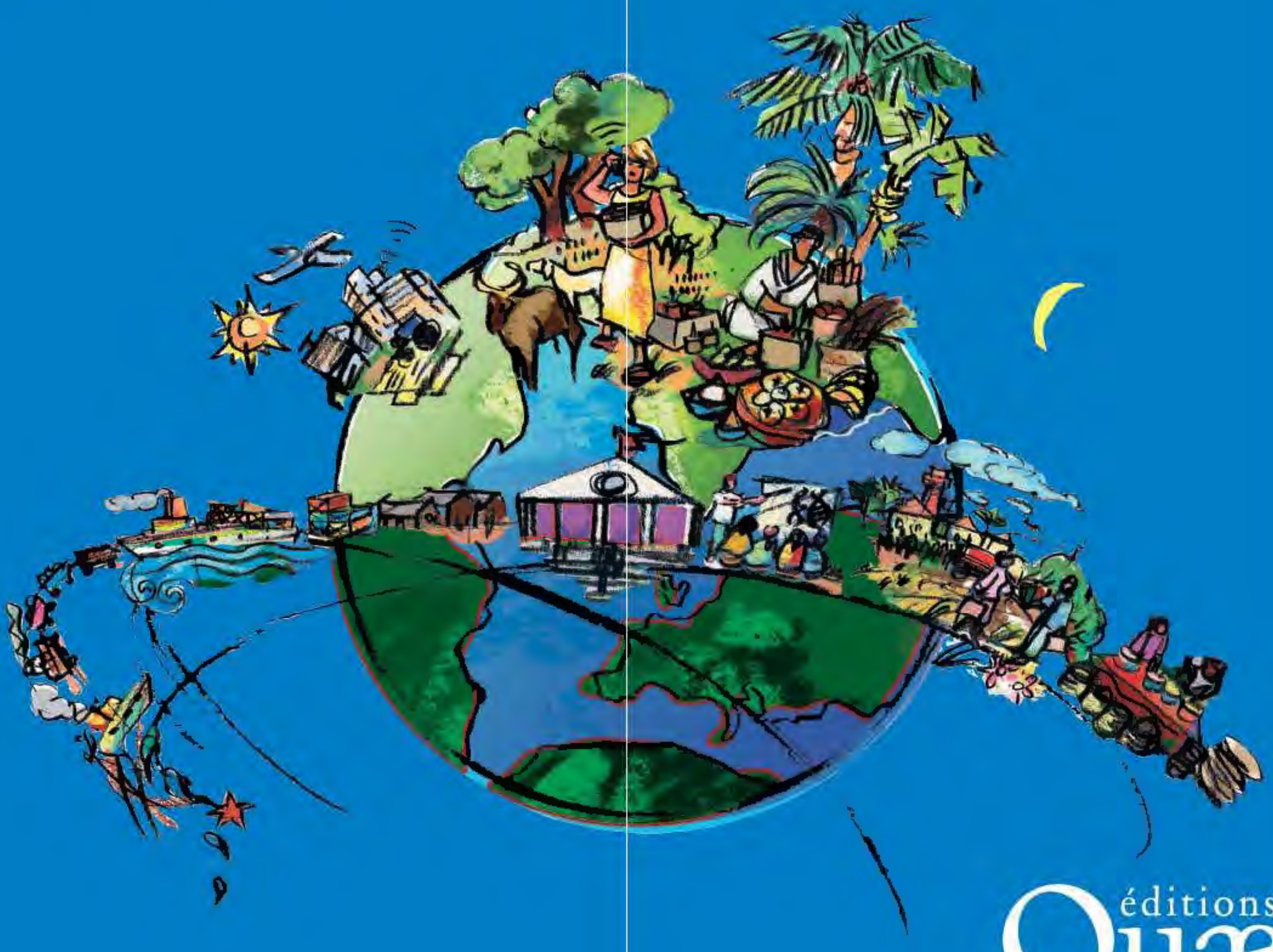

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Agence française de développement
5 rue Roland Barthes, 75598 Paris Cedex 12, France
www.afd.fr

Éditions Quæ
RD 10, 78026 Versailles Cedex
www.quae.com

 ISBN: 978-2-7592-2731-0

Version française : « Des territoires vivants pour transformer le monde »

 ISBN : 978-2-7592-2654-2

Chapter 32

Assessing the capacity of cropping systems to respond to challenges of sustainable territorial development

Mathieu Vigne, Angel Avadí, Michael S. Corson, Jonathan Vayssières and Tom Wassenaar

While agricultural activities can contribute to territorial development through the use and management of space, or by participating in local cohesion, identity and economic activities, they can also affect development negatively. This happens most often with the intensification of productive processes, resulting in a decoupling of short-term production objectives from long-term environmental and social ones. In the case of anthropized ecosystems, these contributions refer to the notions of ecosystem services and dis-services[1] (Karsenty *et al.*, 2009). They can also be compared to the economic concept of externalities[2], even though this concept is limited to effects that are not commercially traded.

Nevertheless, the assessment of these contributions, necessary for promoting the sustainable development of a territory, is complex. First, because these contributions are numerous, interrelated and sometimes difficult to quantify. Second, because the sustainable development of a territory is the result of compromises between different dimensions of sustainability that not only necessitate interdisciplinary approaches, but also normative frameworks whose relevance can be called into question. And finally, because the very concept of territory, as the sphere of influence of production systems interacting with different ecosystems and resources, is difficult to establish (Chapter 1). Furthermore, territories are currently considered differently when evaluating these contributions. The first modality consists of considering the territory as a level of organization in which the agricultural systems to be assessed are situated. The second considers the territory as a space of interaction between agricultural

1. Material and non-material benefits (services) or losses (dis-services) derived from ecosystems in their natural state or modified by human practices.

2. Defined here as the effects the activities of a person or company have on other activities. Externalities can harm or benefit others – in other words, they can be negative or positive.

activities, other activities, and the ecosystems on which they are based. The territory becomes the subject of the assessment. These two approaches not only substantially influence the methods that are used, but also the application of the results to support the sustainable development of territories.

The territory as a level of organization

In an assessment, the territory is often considered as a level of organization of agricultural activities. The object of the study is then limited to production systems, to the supply chain, or even to the entire agricultural sector, without exhaustively considering other actors of the territory. The ecological footprint[3] of the system under study is not necessarily restricted to the territory in which it is situated.

Thus, in addition to the direct access to locally produced food, agricultural activities also promote economic access to food through income generation. In several territories, livestock husbandry in particular is one of the few economic opportunities for the most deprived, such as the landless and the nomadic populations, and is a factor of social integration in areas where youth unemployment is high. For example, by using the ALive LSIPT tool (Box 32.1), Alary *et al.* (2011) show that, in the Sahelian zone of Mali, livestock activities contribute to more than 45% of the income in the households studied, even for those that are more oriented towards agriculture in the strictest sense. Agricultural activities also play a catalyzing role for other sectors of activity in the territory. In particular, they promote job creation through the establishment of supply chains and associated support services. The agrifood sector as a whole (collectors, wholesalers, transporters, processors, suppliers of inputs, distributors, restaurant owners) is thus one of the most promising in terms of job creation for young people with low or medium levels of qualification (Bricas and Broutin, 2006). In Benin, for example, a 1999 employment census indicated that the agrifood sector accounted for 41% of national employment. In a better referenced context, such as that of Réunion Island, it was shown, using the method of assessing effects, that a poultry farmer contributed directly and indirectly to maintaining the equivalent of approximately 15 minimum-wage (SMIC) earners in Réunion and two in metropolitan France (Thévenot, 2014).

From an environmental point of view, various processes induced by agricnlture, such as the extraction of raw materials or the elimination of excess nutrients into different biophysical compartments of the territories (water, soil, air) can negatively affect their sustainability through processes such as eutrophication, acidification, increased toxicity, or changes at a more global scale (climate change). It therefore appears necessary to identify and quantify these risks, and to propose scenarios capable of reducing these impacts. For example, the carbon (C) balance helps identify the emission and sequestration potentials of grazed pasture ecosystems. Its application in an arid environment in the service area of a borewell located in Widou, in the north of Senegal, has shown a negative greenhouse gas balance (-0.01 T CO_2-eq/ha/yr) for the study area (Assouma *et al.*, 2014). In wetlands, this balance, estimated by the Carpagg project on 30-year-old Guyanese grasslands, could be as high as -1.2 ± 0.5 T CO_2-eq/ha/year (Blanfort

3. The ecological footprint (Wackernagel and Rees, 1996) is defined here as the ecosystems and populations impacted by the agricultural activities being assessed.

et al., 2014). The nutrient balance helps determine potential losses to the various environmental compartments of the territory, as well as associated pollution risks. An approach based on the quantification of biomass flows at the level of production systems, and the analysis of their nitrogen (N) content makes it possible, for example, to analyze the efficiencies of N utilisation in the various compartments of the system. Its application in Madagascar (Alvarez *et al.*, 2014), Senegal (Audouin *et al.*, 2015) and Burkina Faso (Diarisso *et al.*, 2015) have shown that the rates and locations of N losses differ according to contexts and production systems.

However, these assessments offer only a limited view of the potential contributions of production systems to their local environment. A life cycle assessment using statistical models could account for the consumption of resources and emissions associated

Box 32.1. The Livestock-Poverty Toolkit (LSIPT).

Céline Dutilly and Mathieu Vigne

In the early 2000s, some international organizations believed that many countries in sub-Saharan Africa had not paid enough attention to the livestock sector's potential for reducing poverty and supporting economic growth (Blench *et al.*, 2003). As a result, a toolkit for investment and policy development in the livestock sector (Livestock-Poverty guide, LSIPT Livestock Sector Investment and Policy Toolkit) was developed as part of the ALive Partnership for Livestock Development, poverty alleviation and sustainable growth in Africa (www.alive-online.org). Its design was entrusted to a group of research and development institutions: CIRAD, IIED, FAO PPLPI (Pro-Poor Livestock Policy Initiative), World Bank, etc.

The proposed process involves three principal phases:

– a preparatory phase to identify and collate a robust and coherent set of data and information on the sector;
– a technical, financial and socio-economic diagnosis phase based on quantitative data and modelling at the three livestock activity levels: micro-economics (livestock systems and households), meso-economic (analysis of the chains) and macro-economic (contribution to GDP and food security);
– a phase of assessing funding and investment opportunities in the sector by developing investment plans based on solid data and presenting a case for investment. This activity follows the logic and process of CAADP (http://www.caadp.net), which supports investment plans promoted by countries in the agricultural sector, with the outcomes and recommendations prepared by the actors for presentation to entities such as finance ministries, planning ministries, international agencies, donors and the private sector.

The diagnostic phase and the assessment tools for the sector were proposed by CIRAD (Alary *et al.*, 2014). The revenue-based approach makes it possible to estimate incomes, both direct as well as indirect (animal traction and use of fertilizer by the agricultural sector), monetary and non-monetary (self-consumption, bartering) of all livestock farming activities from the level of the herd to that of the national economy. LSIPT has been implemented in Mali, Zambia, Ethiopia and, recently, in Tanzania.

with a production system or product throughout its life cycle (Jolliet *et al.*, 2010). It is thus an improvement in the representation of potential impacts or damage. A review of life cycle assessments applied to perennial crops (Bessou *et al.*, 2013) has shown that, in most production chains, the cropping system appears to be the main contributor to global warming, eutrophication and potential impacts of toxicity. Reducing the environmental impact of agricultural production therefore mainly comes down to focusing on territories where cropping systems are located. On Réunion Island, the life cycle assessment of the poultry chain, whose main links are located within the same territory, showed a variable contribution of production systems to environmental impacts induced by the chain (Thévenot, 2014). Consequently, although these production systems are responsible for much of the eutrophication risk from soils used in the chain, directly in Réunion and indirectly in other territories (maiuly for food production), they are little involved in the direct emission of greenhouse gases resulting from the chain's activities.

The assessment of livestock husbandry shows that its social contributions appear to be limited in comparison to economic and environmental approaches. Nevertheless, the latter are known. In contrast, even though the social, cultural and symbolic dimensions of livestock have been well highlighted (HLPE, 2016), their quantification is complex. Among the methods proposed to do so, the analysis of social impacts during the life cycle (called 'social LCA') could be interesting (Macombe *et al.*, 2013), but it is still not widely undertaken. It explores, for example, the effects of income inequalities on the health of local populations (Feschet *et al.*, 2013) or on health risks associated with agricultural activities (Di Cesare *et al.*, 2016). Consequently, such a method also focuses on the territory, both for its scale as well as an object of study. It would be all the more useful if, combined with other analytical frameworks, it could be used for a multi-criteria assessment allowing a comprehensive analysis of the multiple contributions of livestock systems to the sustainability of their territories, since such analyses are often qualitative at the moment (Vall *et al.*, 2016). In Benin, for example, the IDEA method[4] was used to assess the sustainability of market gardening production (Ahouangninou *et al.*, 2015). This method proposes a comprehensive approach to the sustainability of agricultural production systems through self-assessment. To this end, it incorporates agroecological, socio-territorial and economic dimensions in order to assess the strengths and weaknesses of the system using quantified indicators, and to identify ways of improving sustainability. The socio-territorial sustainability assessed in the method refers to ethics and human development (Vilain *et al.*, 2008). It characterizes, on the basis of the farmer's quality of life and the amount of market or non-market services, the integration of the farm in the territory to which it belongs and in society.

Life cycle assessment for territorial development

Although life cycle assessments have often been carried out at higher levels, they have traditionally been centred on the plot, farm and production system, to complement models that are primarily dynamic. They thus open the door to the optimal

4. http://www.idea.chlorofil.fr (retrieved 30 March 2017).

use of energy and the looping of carbon and nutrients cycles across several farms to conserve natural resources while optimizing production. The so-called 'territorial' analysis of environmental impacts over the life cycle can thus take into account exchanges between farms (e.g., manure and fodder), landscape management (e.g., distribution of agricultural activities) and centralized activities (e.g., the treatment of livestock effluents). Various approaches have been applied to estimate pollution emission flows and environmental impacts of all agricultural production at the level of a territory such as a watershed (Moreau *et al.*, 2013; Avadí *et al.*, 2016). The spatialized territorial approach, which integrates dynamic models, is all the more interesting as it allows a better consideration of the influence of spatial and temporal variability on emissions and of the environmental impacts of a territory (Nitschelm *et al.*, 2016).

However, taking into account all production systems and processes is onerous. Recent approaches have thus attempted to describe the environmental performance of a territory's agricultural sector by extrapolating life cycle assessments of farms using statistical or model-based methods (Box 32.2). For example, in order to assess the environmental impacts of an irrigated territory in Tunisia, Pradeleix *et al.* (2012) proposed the 'diagnosis of agrarian systems' as an approach adapted to situations lacking reliable statistical data. This approach culminates in the modelling of different production systems by taking into account the diversity of actual farming practices. Unlike statistical approaches, it establishes clear causal relationships within the framework of the functioning of each type of agricultural system identified. It also considers the complexity of the territory, from the global to the particular, and analyzes agricultural activities at different scales.

The territorial life cycle assessment presents modelling challenges, in addition to those normally expected from conventional agricultural life cycle assessments (Caffrey and Veal, 2013), such as the representation of the agricultural sector on the basis of a few farms. At present, it is necessary to have a statistically representative sample of farms in the territory for generalizations to make sense. The recourse to a typology of farms, ideally based on biophysical factors, seems relevant because a life cycle assessment is essentially a framework for biophysical accounting. However, this approach is still being developed, since the aggregation of individual farms and the taking into account of the inherent variability remain unsolved, and since life cycle assessments have traditionally focused on systems at smaller scales. A comprehensive assessment of a territory's activities or, at the very minimum, of all those that interact with agricultural activities, is also a significant challenge. Loiseau *et al.* (2013) thus propose a life cycle assessment framework adapted to a territory's environmental assessment, i.e., to all of its activities of production and consumption. Applied to the Bassin de Thau, a lagoon in southern France, it has permitted the determination of the relative role of agriculture in the environmental balance in the territory in relation to other production and consumption activities (Loiseau *et al.*, 2014). This approach could therefore be relevant for the territory's sustainable development by providing the environmental assessment of various planning scenarios. However, it requires significant amounts of data and a detailed knowledge of the interactions between activities.

Box 32.2. Territorial life cycle assessment for an *ex ante* evaluation of the environmental consequences of implementing agricultural strategies in two territories in Brittany.

Angel Avadí and Michael Corson

The goal of the European CANtogether FP7 project is to design, assess and promote new agricultural systems and practices linking livestock production and cropping systems at the farm and regional level in an effort to optimize energy, carbon and nutrients flows. Territorial life cycle assessments for this project were carried out for three case studies: the intervention areas of a cooperative (Coopédom) and a watershed area in Brittany (Lieue de Grève) in France and a mountainous area with low and high altitudes in Switzerland (Thurgau and Grisons cantons).

An approach used in this project for Lieue de Grève (Avadí *et al.*, 2016) and Coopédom was to establish an initial categorization of farms in the territory through a hierarchical grouping of major components. Subsequently, a life cycle assessment was carried out for each farm, and the impacts of each farm category (per hectare or per kg of agricultural product) were calculated from different farms in the category, either as an average of the impacts or by using linear regressions between structural characteristics and estimated impacts obtained from the life cycle assessment. The sum total of the territory's impacts (for its total agricultural area or its total production of an agricultural product) was calculated as the sum of impacts of different farm categories. This approach was used to predict the effect on regional environmental impacts due to the implementation of certain agricultural management strategies, such as extensification or intensification of dairy production, by complementing and validating the results of the dynamic models* used in the same territory.

For example, when applying the approach to an innovation scenario involving dairy and mixed (milch and meat breeds) farms in Lieue de Grève (average stock density reduced from 2.7 to 1.4 large cattle unit/ha of grassland, number of milch cows increased by 15% to maintain milk production from each farm, increased grassland area, and maize silage reduced accordingly, to provide the necessary fodder mass for the largest herd, and surface area of all other crops reduced to maintain the UAA of each farm), the results estimated a reduction in the regional eutrophication (-11%) in the same order of magnitude as predicted by modelling N at the level of the watershed (-26%) (Moreau *et al.*, 2013). The eutropbication potential was reduced by 15% per tonne of milk. Potential impacts decreased from 5 to 54% per hectare per tonne of milk in all other impact categories, due to a reduced intake of concentrated feed and fertilizers. In the regional context, where eutrophication is a major concern, there is a need to reduce the impact of eutrophication per hectare.

*The life cycle assessment accounts for, in association with static models, the consumption of resources by and emissions associated with a production system or a product, over its entire life cycle (Jolliet *et al.*, 2010).

The territory as a subject for assessment

While the farm has long been considered the most appropriate level for decision-making and strategic management in agriculture (Del Prado *et al.*, 2013), there is a growing interest in policy assessment and agricultural management strategies at the territorial level (Payraudeau and van der Werf, 2005). This interest is illustrated by the emergence of approaches in which the territory is considered a subject for study in its own right. In these approaches, it is considered a socio-economic system whose economic and social activities are based on local ecosystems. The agricultural sector is thus considered as one of the components of the territory.

Territorial ecology, an emerging discipline, is interested for example in the flows of materials and energy between the different components of a territory (Barles, 2014). In this way, it highlights the catalytic role of certain agricultural activities in the territories (Wassenaar, 2015). Territorial ecology uses methods such as the modelling of materials and energy flows, and the analysis of substance flows.

The studies carried out by CIRAD show that livestock husbandry plays a major role in these dynamics. A study in the groundnut production basin of Senegal focused on measuring the incoming, outgoing and circulating biomass flows between different components of three interconnected systems: the terroir, the household and the plot. These flows concerned the main products of the tree layer, crops (grains, residues, etc.), livestock (organic manure, animals, milk, etc.) as well as the main inputs (mineral fertilizers, concentrated feed, foodstuffs, etc.). The study focused on two villages with different trajectories (Audouin *et al.*, 2015): Diohine, where collective resources managed by the organization of a common fallow highlighted inter-household interactions; and Barry Sine, where a more individual and more intensive resource management system resulted in the emergence of sheep fattening and the maintenance of commercial groundnut cultivation. In spite of a greater productivity at the terroir level for Barry Sine, animal herds played a major role in the organization of the N cycle in both villages, accounting for 60 to 80% of N flows.

Finally, in a rural sub-prefecture typical of the savannahs of West Africa (Koumbia, Burkina Faso), a study first aimed at estimating the total biomass productivity of the territory based on the mapping of the sub-prefecture and the typology of the different agroecological environments. The use of this biomass for different human activities and its exchange between activities were then estimated (Blanchard *et al.*, 2015). The results showed that despite the low percentage of biomass consumed directly by animals (11%), the latter account for more than a quarter of the biomass exchanged in the territory, thus actually promoting integration between agriculture and livestock husbandry.

However, the role of crops in these biomass flows cannot be overlooked. In particular, they offer the means for deriving value, through organic fertilization, from non-agricultural resources available in the territory. In Réunion, for example, the Girovar project identified three scenarios corresponding to three types of fertilizer products, which were relevant to the needs of Réunion's agriculture, and were made from organic waste products of agricultural and non-agricultural origins available. Co-constructing such scenarios and verifying their performance requires tools to represent flows within a territory (see Chapter 33). In addition, these scenarios are able to provide information to several assessments for testing their sustainability. Thus, while socio-economic viability and acceptability are criteria that are explicitly and universally considered in the development process, the same is not true for the environmental dimension. Dumoulin *et al.* (2016) have recently proposed a framework that helps, as pertinently as possible, keep such a process informed (with reference to the perception of the actors concerned and the biophysical characteristics of the territory in question) about the gamut of environmental consequences that could result from the envisaged development. This is, however, not an off-the-shelf tool; it requires the deduction and rigorous construction of a set of *ad hoc* indicators, each of which must be estimated by a specific method.

Without claiming to be exclusive, these approaches to territorial ecology call for combining various tools such as systemic modelling (e.g., multi-agents), life cycle assessments, biophysical models or exposure models. Such integrated approaches provide a dynamic and more holistic view of the impact of the evolution of systems and the agricultural sector on the other components of the territory, and consequently on territorial development.

Conclusion

The assessment of the contribution of production systems to the sustainability of territorial development seems to be still incomplete. It is especially affected by a methodological failure and a lack of coherence between different approaches for an overall assessment of this contribution. Few approaches have so far proposed taking into account the wide range of environmental, economic and social impacts associated with activities in a territory. The methodological immaturity of certain approaches, which is partly due to their recent emergence, is also a factor. However, past and current initiatives show a strong dynamism, mainly linked to the interest in assessing sustainability at levels such as the territorial. It seems therefore essential to support this interest, especially to find solutions to some conceptual and methodological problems of changes in scale that are still unresolved.

The question of the relevance of the additivity of environmental impacts is still rarely addressed. The extrapolation of individual externalities specific to each system at higher scales is too often treated as the oversimple sum of these individual externalities. Furthermore, territorialized indicators that take into account trade-offs between the different systems must be developed. Finally, an understanding of territorial dynamics is indispensable for accompanying agricultural systems along trajectories that favour their own sustainability, while encouraging their contribution, through their positive externalities, to the sustainability of overall territorial development. Indeed, subjected to different influences, the agricultural activities evolve together with territories. Using the example of the reconfiguration of seven dairy farming basins, Napoléone *et al.* (2015) threw light on their evolutions through the interlinked development of livestock systems, territories and sectors on which they depend. However, understanding these territorial dynamics requires a complex set of data, in terms of the temporal dimension, as well as the number of actors, levels of organization and processes involved. It is therefore a question of being able to set up, in conjunction with local stakeholders, observatories for agricultural territories (see Chapter 37), especially in the countries of the Global South, where there are few long-term monitoring systems, and where the collection and storage of information is poorly structured (Vall *et al.*, 2016).

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